TOPIC 06 – KINETICS
6.1: RATES OF REACTION

IB Chemistry

T06D01

6.1 Rates of reaction - 2 hours

- 6.1.1 **Define** the term rate of reaction. (1)
- 6.1.2 **Describe** suitable experimental procedures for measuring rates of reactions. (2)
- 6.1.3 **Analyze** data from rate experiments. (3)

6.1.1 – Rate of Reaction

- 6.1.1 **Define** the term rate of reaction. (1)
- The branch of chemistry concerned with rates and the sequence of elementary steps in a reaction is called **reaction kinetics** or **chemical kinetics**.
- The study of kinetics allows us to:
  - Determine how quickly a reaction will take place
  - Determine the conditions required for a specific reaction rate
  - Propose a reaction mechanism

6.1.1 – What is a rate?

- Some reactions are very fast, such as neutralization or precipitation reactions.
- Some reactions are slow, enzymatic oxidation of fruits, or even slower rusting of iron.
- The **rate** of a chemical rxn is a measure of ‘speed’ of the reaction
  - The rate refers to the change in the amount (or concentration) of reactant or product

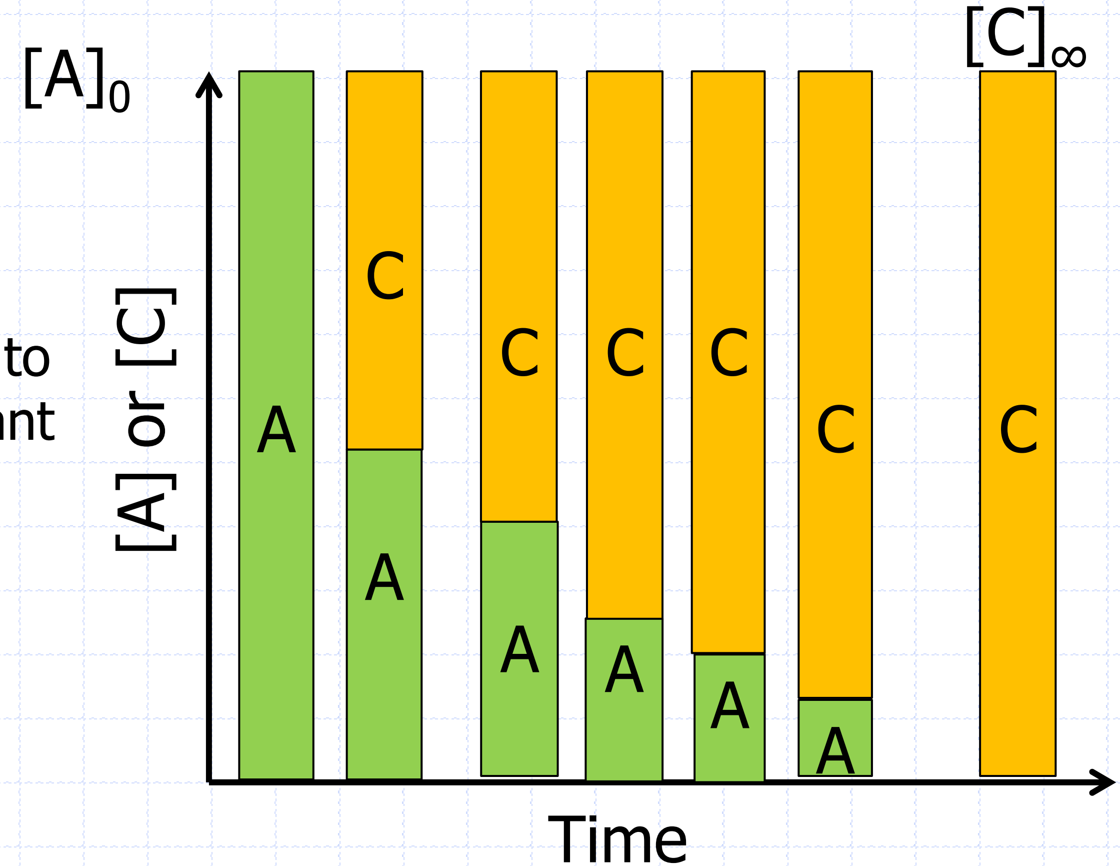
6.1.1 - Factors That Affect Reaction Rates

- **The Nature of the Reactants**
  - Chemical compounds vary considerably in their chemical reactivities.
- **Concentration of Reactants**
  - As the concentration of reactants increases, so does the likelihood that reactant molecules will collide.
- **Temperature**
  - At higher temperatures, reactant molecules have more kinetic energy, move faster, and collide more often and with greater energy.
- **Catalysts**
  - Change the rate of a reaction by changing the mechanism.

6.1.1 – Calculating Rates

- The rate is defined as the change in concentration or amount of a reactant or product with time, t:
- Rate = ______________ = __________

This figure is the graphical method of visualizing how reactant and product concentrations are related to time. [A] represents reactant concentrations, [C] represents product concentrations.



6.1.1 – Rate Determination

- In symbols:
  - Rate = —— or Rate = —— *(calc notation)*
  - *The usual units for reaction rate are moles per cubic decimiter per second*
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6.1 – Rate Example #1

- 0.04 mol of a substance is produced in a 2.5dm^3 vessel in 20 seconds. What's the rate of reaction?
  - Determine the amount produced in 1.0 dm^3
    - [ ]
  - Determine the amount produced per second
    -

6.1 – Rate Example #2

- 22 grams of CO_2 is produced in 15 seconds in a vessel of capacity $4dm^3$
  -
  - Adjust the volume and time:
    -
    -

6.1 – Rate Example #3

- Acidified hydrogen peroxide (H_2O_2) and KI(aq) react according to the following equation:
  - $2H^+(aq) + H_2O_2(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2H_2O(l)$
- It was found that ______ after allowing the reactants to react for 30 seconds.
- Calculate the average rate of formation of I_2 in 30s:
  - This means on average, 2×10^{-3} mol I_2 are being formed dm^{-3} (L) ever second

6.1 – Relative Rates in Equation

- If the balanced equation for the overall reaction is known, then the rates of change in concentrations in all reactants and products are related to each other via the coefficients in the balanced equation.
- Any reaction can be represented by the following:
  - aA + bB → cC + dD
  - Reactants → Products
  - Rate = – [ ]/___ – ___ – [ ]/___ – ___
  - Rate = – [ ]/___ – ___ – [ ]/___ – ___
    - Negative sign indicates [decrease]
    - Positive = [increase]

6.1 – Example #3 Continued

- For example, back to the hydrogen peroxide prob.
- $2H^+(aq) + H_2O_2(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2H_2O(l)$
- Average rate of appearance of I_2:
  -
- The average rate of appearance for water is twice that of I_2 because 2 moles of water are formed for every mole of iodine
  -
  - [ ]

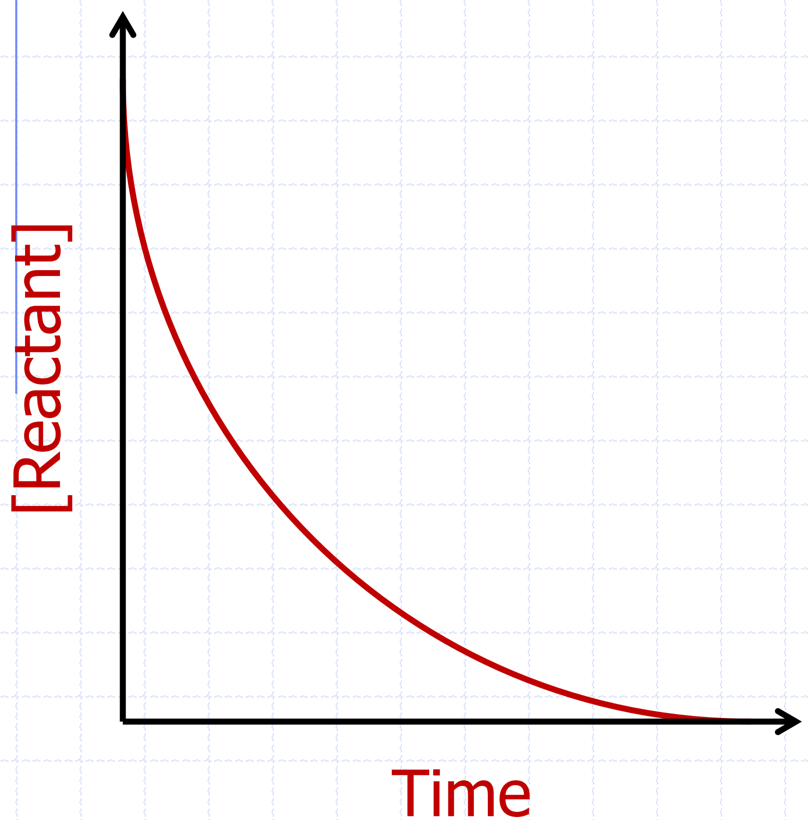
6.1 – Example #3 Continued 2

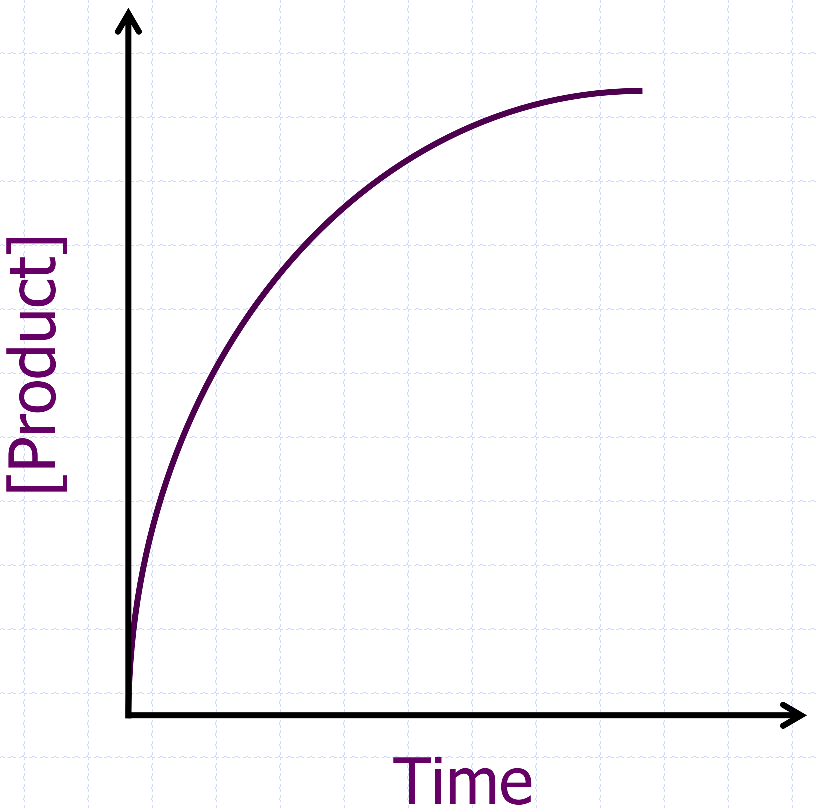
- For example, back to the hydrogen peroxide prob.
- $2H^+(aq) + H_2O_2(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2H_2O(l)$

Rate of Reactant Depletion = Rate of Products Formation

- _ [ ] _ [ ] _ [ ]
- _ [ ] _

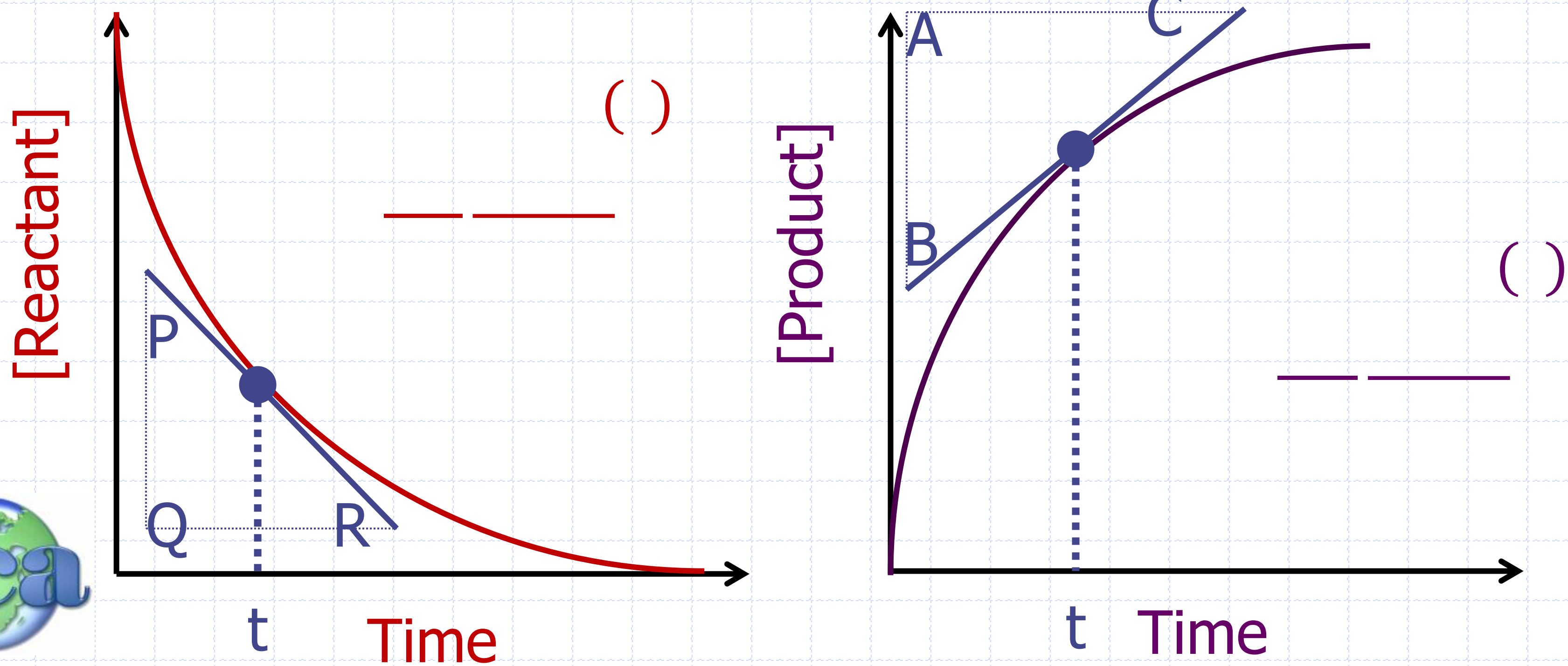
6.1 – Graph Reactant/Product v Time



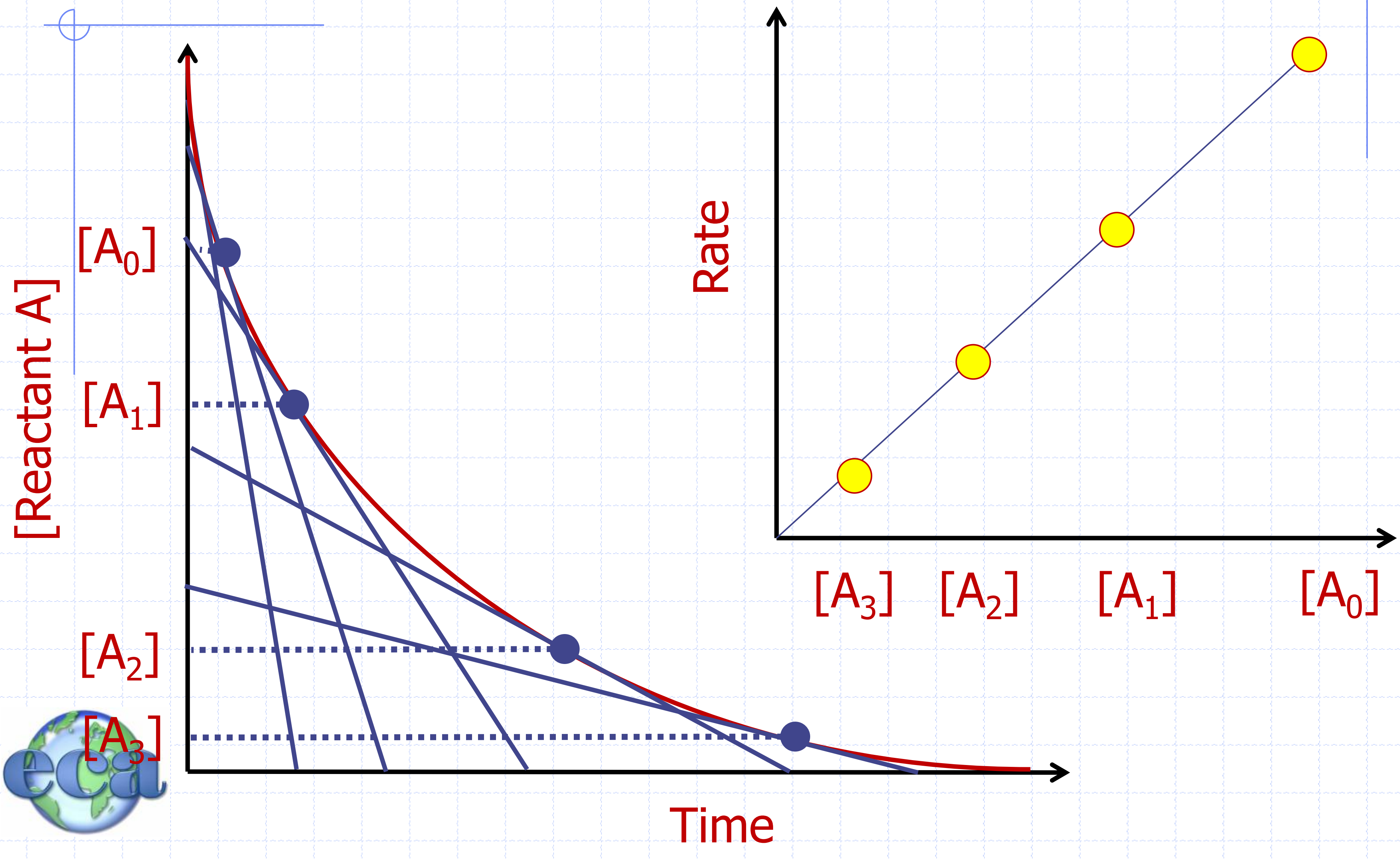


6.1 – Instantaneous Rate of Rxn

- The **instantaneous rate of reaction** can be determined graphically from a graph of product or reactant concentration (or amount) vs time.
- This will show the rate at a given time (or point) rather than the average rate over a time interval:



6.1 – Rate Change / Time

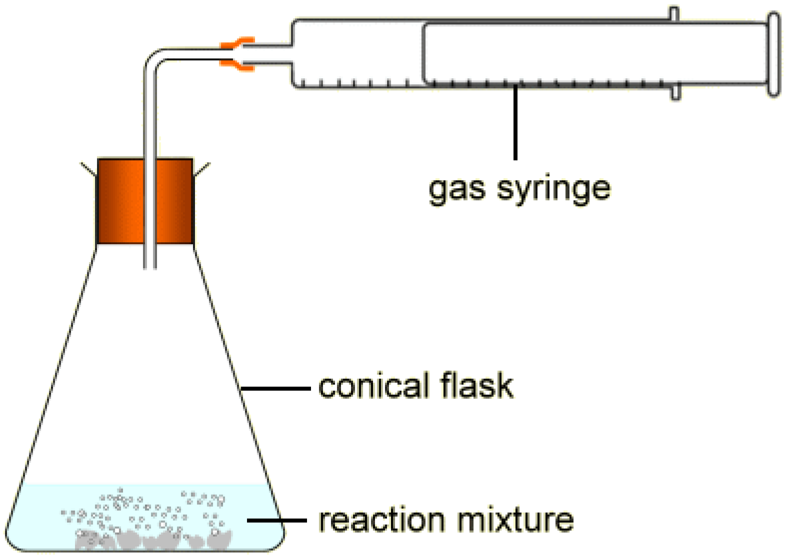


6.1.2 – Experimental Procedures

- 6.1.2 **Describe** suitable experimental procedures for measuring rates of reactions. (2)
- Reaction rates can be monitored during (but not limited to) changes in the following:
  - Color
  - Formation of a precipitate (solid)
  - Change in mass (gas produced causing loss, etc)
  - Volume of gas produced
  - Time taken for a given mass of a product to appear
  - pH
- Temperature

6.1.2 – Reactions Producing Gas

- Collection of the gas produced at regular time intervals (keeping P constant)
- A gas syringe is often used or inverted buret in water
- $Mg(s) + 2HCl\ (aq) \rightarrow MgCl_2\ (aq) + H_2\ (g)$



6.1.2 – Change in Mass

- This does not disobey the law of conservation of mass
- If a gas is given off, the solid products will have a different mass than the reactants
- Gas must be heavier than say H_2 to work
- $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O$

6.1.2 – Change in transmission of light

- Colorimetry or Spectrophometry
- If one of the reactants or products is colored and has an absorption in the visible region (320-800nm)
- As concentration of one material increases or decreases, a change in absorption at that spectrum is apparent
- $2HI(g) \rightarrow H_2(g) + I_2(g)$
  - HI and H_2 are both colorless
  - I_2 is a colored gas

6.1.2 – Change in concentration measured with titration

- At time intervals, collections of the product can be tested by titrating against a ‘standard’ (known) value
- To keep materials from continuing to react after samples are drawn they can be **quenched**. A material is added which effectively stops the reaction in the sample at the moment it’s withdrawn. Like a ‘freeze frame.’
- $H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow I_2(g) + 2H_2O(l)$

6.1.2 – Change in concentration measured by conductivity

- The total electrical conductivity is dependent on the concentration of ions in solution
- Measured using a conductivity meter
- $BrO_3^-(aq) + 5Br^-(aq) + 6H^+(aq) \rightarrow 3Br_2(aq) + 3H_2O$
- A sharp decrease in the concentration of ions (12 $\rightarrow$ 0) is observed, corresponding to a large decrease in conductivity of the solution.

6.1.2 – Non-continuous methods of detecting change in reaction

- Sometimes it's difficult to record a continuous change in the rate of reaction.
- In these cases, it may be more convenient to measure the time it takes for a reaction to reach a fixed point (something observable and most likely qualitative)
- The 'end point' is recorded and the clock is stopped, which is why they are known as **clock reactions**
  - $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$
    - Certain time taken for a certain size of Mg ribbon to react completely (no longer visible) with dilute acid